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POLYMERIC MATERIALS IRRADIATION

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Prepared For:

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FOREWORD

This data is submitted to the Astrionics Laboratory of the George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Alabama, in accordance with the requirements of Task Order No. ASTR-LGC-10, ASTR-LGC-17, and ASTR-LGC-25 of Contract No. NAS 8-5332. The data is a compilation of physical and electrical measurements performed on polymeric materials after exposure to nuclear radiation. The test was performed by the Georgia Nuclear Laboratories, Lockheed-Georgia Company.

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1.0 TEST PROCEDURE

The test specimens were exposed to nuclear radiation at the GNL RER while in a vacuum environment. They were divided into three groups by the Astrionics Laboratory: a Control Group, Group I and Group II.

The Control Group specimens received no radiation while the Group I specimens were exposed to a dose of 5.0×10^5 r and 7.7×10^{11} n/cm^2 (E > 0.5 MeV) and Group II to 1.4×10^6 r and 1.2×10^{14} n/cm^2. After irradiation all specimens were subjected to electrical and physical tests. The data derived from these tests are contained herein.

1.1 TEST SPECIMENS

The materials irradiated along with the number of specimens are tabulated in Table I. The specimens were supplied by the Astrionics Laboratory of MSFC. Specimens were fabricated in several forms, each applicable to particular electrical or physical tests. One group of specimens is shown in Figure 1.

1.2 TEST ENVIRONMENT

The specimens were located in a vacuum chamber during irradiation. Vacuum and temperature were continuously monitored.

1.2.1 Temperature

The temperature profile of the specimens during irradiation is shown in Figure 2.

1.2.2 Vacuum

The vacuum during irradiation is shown versus time in Figure 3. The sharp decrease of vacuum immediately after initiation of the radiation indicates outgassing of the

specimens due both to increasing temperature (gamma heating) and radiation induced off gassing.

1.2.3 Nuclear

Both the neutron and gamma environment were monitored and reported for the polymeric materials. These specimens received an average gamma dose for Phase I of 5.0×10^5 r and 7.7×10^{11} n/cm^2 (E > 0.5 MeV). For Phase II the specimens accumulated additional radiation until the total exposure reached 1.4×10^6 r and 1.2×10^{14} n/cm^2. The radiation rates were of the order of 1.4×10^3 r/hr to 7.8×10^6 r/hr and 3.2×10^9 n/cm^2/hr to 2.1×10^{14} n/cm^2/hr.

. Neutron Flux

Nickel (Ni^{58}) foils were used to provide mapping of the test area. In addition, a foil packet was included to determine the neutron energy spectrum. A graph of fast neutron flux above threshold energy was determined from the data of this foil packet for Phase II and is shown in Figure 4. The materials and reactions utilized in the packet are tabulated below:

Foil Material and Reaction	Effective Threshold Cross Section (1) (barns)	Effective Threshold Energy (1) (MeV)
$S^{32}(n,p)T^{32}$	0.30	2.9
$Ni^{58}(n,p)C^{58}$	1.23	5.0
$Mg^{24}(n,p)Na^{24}$	0.048	6.3
$Al^{27}(n,a)Na^{24}$	0.11	8.1
$Na^{23}(n,r)Na^{24}$ (2)	0.536 (3)	Thermal

(1) Effective threshold cross sections and the corresponding effective threshold energies are calculated on the basis of a neutron spectrum

(2) One sodium 23 foil was cadmium covered and one was bare

(3) 2200 m/s cross section

- Gamma Dose

  Lockheed Model 505 ionization chambers were used to monitor the gamma dose rate to which the specimens were subjected. The model 505 is a graphite - walled CO_2 filled chamber with a sensitive volume of 4 cm^3. Each chamber was calibrated prior to the irradiation in a known Co^{60} source field.

1.3 POST IRRADIATION TESTS

Electrical and Physical tests were performed upon all specimens after irradiation. These tests included dielectric constant, dissipation factor, volume resistivity, dielectric strength, compression strength, tensile strength and hardness. In most cases a specimen was not provided for all these tests for each type material. Also, in a few instances the tests could not be carried out because of peculiarities of the material. Applicable ASTM Standards were followed where possible.

1.3.1 Dielectric Constant And Power Factor

The requirements of ASTM D150-59T were followed to perform these measurements.

The dielectric test samples were cleaned using soap and distilled water and conditioned in a standard laboratory atmosphere (23 $\pm$ 2°C, 50 $\pm$ 5% RH) for a minimum of 48 hours. The testing was conducted in a standard laboratory atmosphere. A General Radio Type 1690A dielectric sample holder was used to contain the specimen for the measurement. Several capacitance bridges were necessary to cover the frequency ranges. At 60 cps a General Radio 1611A capacitance bridge was used; the General Radio 1620 capacitance bridge was used for the 1 kc and 10 kc measurements and the 100 kc and 1 megacycle measurements were performed by the General Radio 716CS-1 capacitance bridge.

Calculations of dielectric constant and power factor were performed using the physical dimensions of the specimens and the correction factors for the sample holder. Three measurements were taken for each specimen and an average of all measurements on all samples is reported.

1.3.2 Volume Resistivity

The requirements of ASTM D257-61 were followed to perform three measurements. The specimens upon which the volume resistivity measurement was performed were cleaned and conditioned similar to those in the dielectric constant and power factor tests. The testing was conducted in a standard laboratory atmosphere.

A Kiethley Model 515 megohm bridge (range up to 10^{15} ohm) was used to perform the measurement. A standard three piece guarded electrode sample holder was used. The time of electrification was one (1) minute with an applied maximum voltage of 500 volts. Three readings were recorded for each sample. The volume resistivity was calculated using the physical dimensions of the specimen and an average of the three values was recorded.

1.3.3 Dielectric Strength

The requirements of ASTM D149-61 were followed to perform these measurements. The test specimens were conditioned similar to those described in the preceeding test. After the width of the specimens was measured, they were placed in a dielectric strength fixture. The surrounding medium was oil and the electrodes were 1/4" in diameter. The ac voltage across the specimen was increased from 0 to the breakdown point at a rate of 500 volts per second. A total of five tests were made on each specimen unless there was a wide deviation between breakdown voltages. A wide deviation required an additional five tests. The breakdown voltage was calculated in terms of the average volts per mil.

1.3.4 Compression And Tensile Strength

The requirements of ASTM D695-61T and ASTM D638-61T were followed to perform these measurements. The dimensions of the specimens were recorded prior to measurement. The specimen was placed in the test fixture and the compressive and tensile deformation was recorded along with the applied stress. Appropriate calculations were performed and that data was reported.

1.3.5 Hardness

The hardness tests were performed in accordance with ASTM D1706-61 for the Durometer tests and with ASTM D785-60T for the Rockwell hardness tests.

The type A Durometer was used and readings were taken at contact and after fifteen seconds. Procedure A of the Rockwell hardness ASTM D785-60T was used.

2.0 TEST DATA

The test data are presented in tables 2 through 20 and figures 5 through 22. Each data number is the average of measurements obtained for all samples of a particular category. A typical tension and compression curve is included for each type material. Tabulated tension and compression characteristics are clarified on the typical curves.

TABLE I MATERIALS, TESTS AND SAMPLE SIZES

Material	Number of Samples Per Test*					
	Resistivity	Dielectric Constant & Dissipation Factor	Dielectric Strength	Hardness	Tension	Compression
Polyurethane - 1538	3/2/3	3/2/3	3/2/3	3/2/3	3/2/2	
Stycast 2651	3/7/5	3/7/5	3/2/5	3/2/5	3/1/0	3/5/9
Stycast 2850 GT	3/0/1	3/0/1	3/0/2	3/0/2	3/3/2	3/8/8
Epoxy C1 - 15%	3/0/1	3/0/1	3/0/1	3/0/1	3/0/1	3/0/0
Epoxy C1 - 75%	3/1/1	3/1/1	3/2/2	3/2/2	3/2/1	3/6/8
Silicone EC1663	2/8/8	2/8/8	2/4/5	2/4/5	–	–
G-10 Fiberglass	–	–	0/7/8	–	0/4/6	–
Silicone LTV 182	3/4/12	3/4/12	3/9/12	3/9/12	3/3/4	4/7/8
Silicone LTV 602	0/1/1	0/1/1	0/1/1	0/1/1	3/4/6	3/9/6
3M - PVC	–	–	0/5/5	–	0/5/5	–
Mylar Film	–	–	–	–	0/9/13	–
P. O. Rayclad	–	–	–	–	0/8/12	–
Polyoloein	–	–	–	–	0/8/12	–
RTV-11	3/8/8	3/8/8	3/4/5	3/4/5	3/2/3	3/6/8
RTV-501	–	2/5/5	2/5/9	2/5/9	2/0/0	4/0/0
Silicone Rubber Sleeving	–	–	0/5/5	–	0/5/5	–
TFE Rayclad	–	–	–	–	0/10/10	–
Teflon	–	–	–	–	0/9/11	3/6/7
Scotchcast XR 5038	3/2/2	3/2/2	3/2/1	3/2/1	3/2/2	3/7/8

*CONTROL/GROUP I/GROUP II

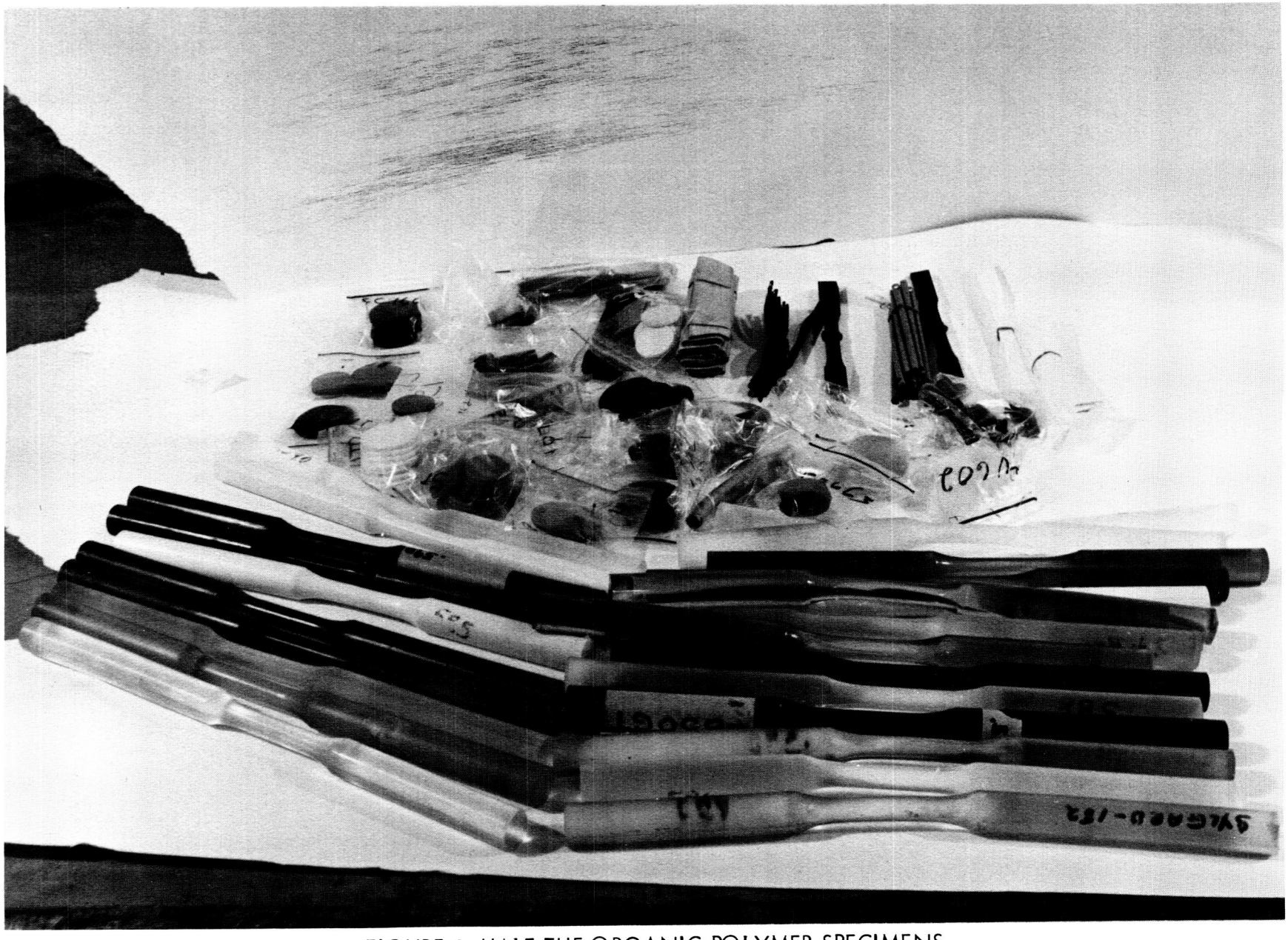

FIGURE 1 HALF THE ORGANIC POLYMER SPECIMENS

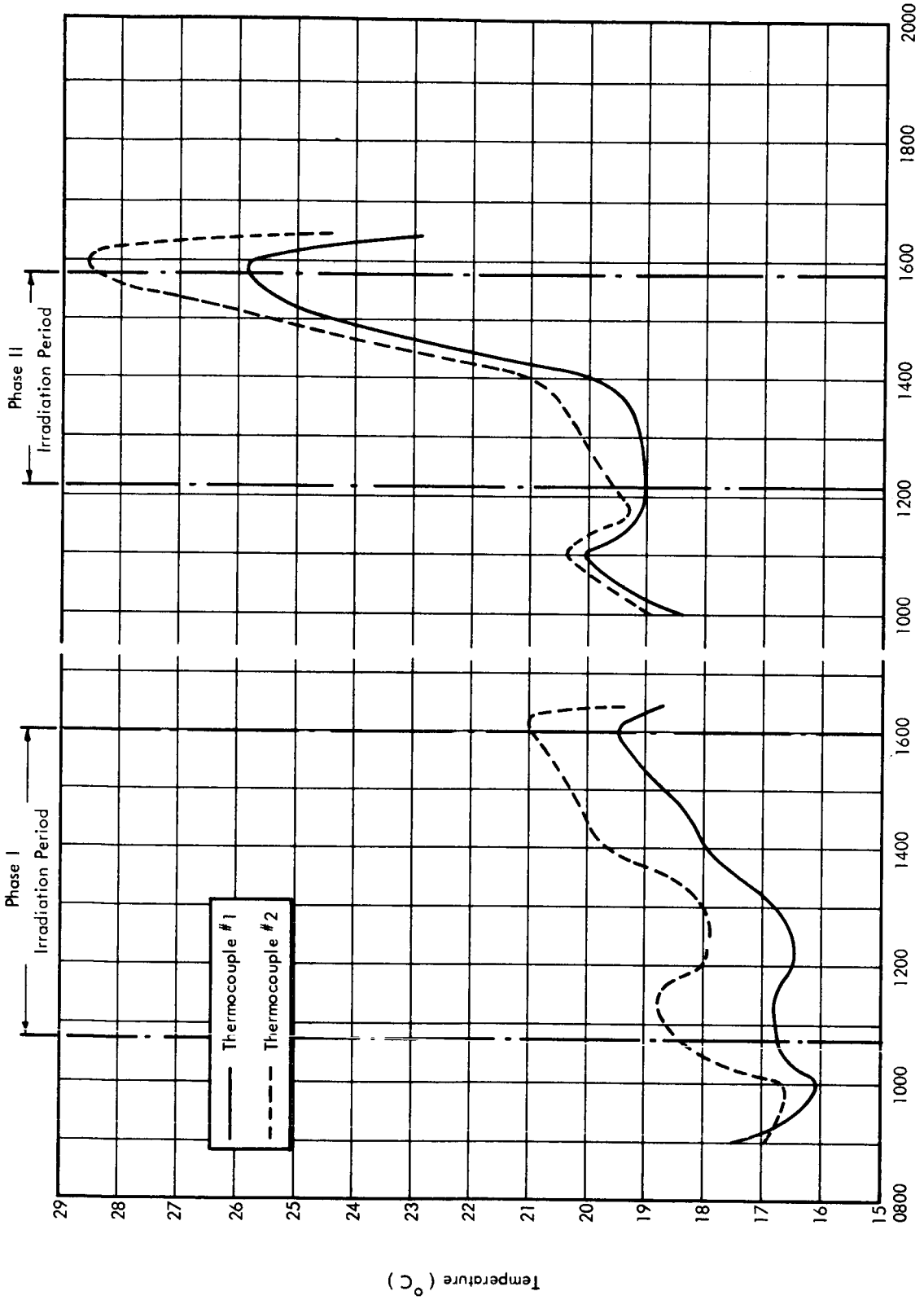

FIGURE 2 TEMPERATURE IN VACUUM CHAMBER DURING IRRADIATION TEST

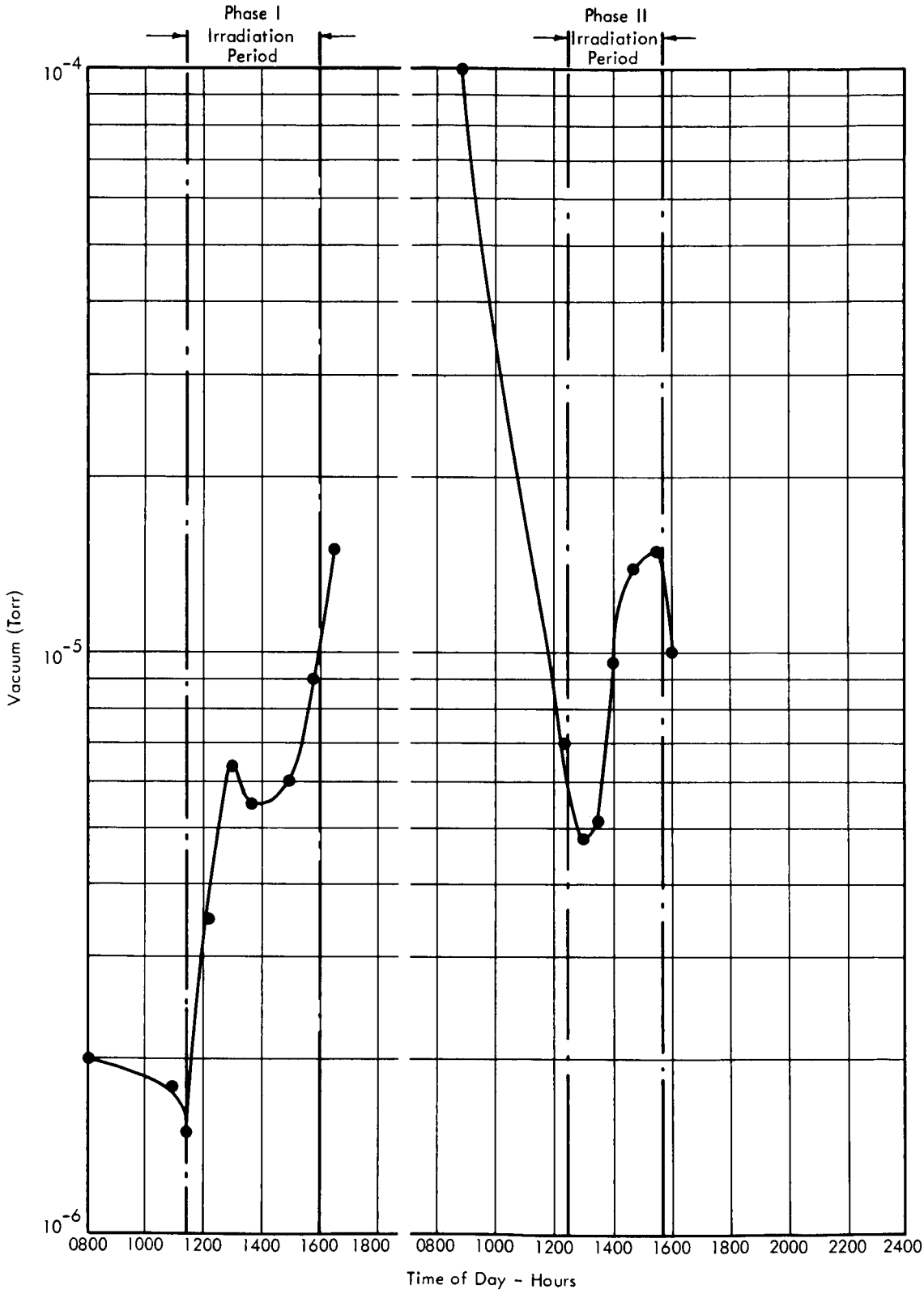

FIGURE 3 VACUUM DURING IRRADIATION

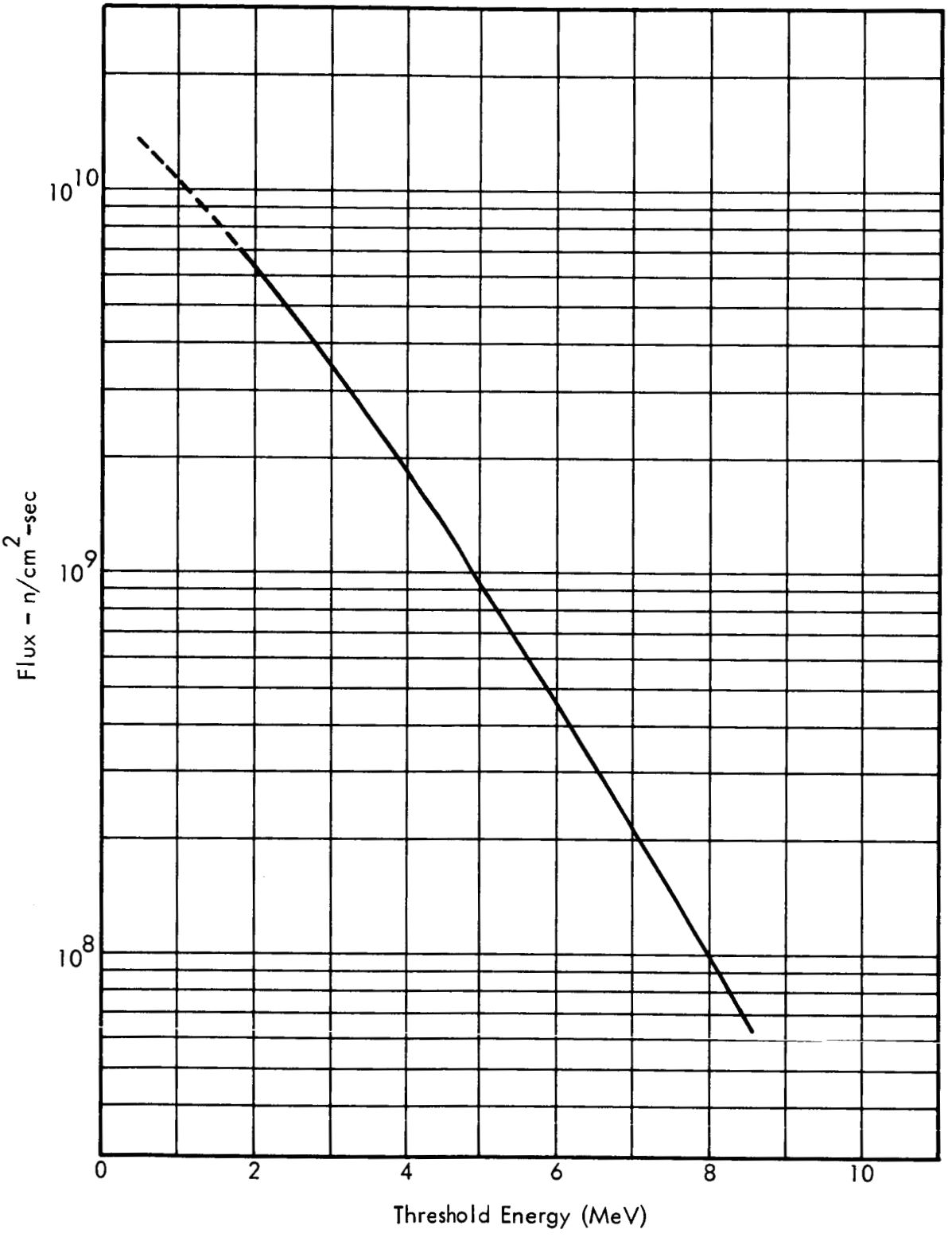

FIGURE 4 FAST NEUTRON SPECTRUM PHASE II

TABLE 2

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: PR-1538

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	7.542×10^{13}	26.348×10^{12}	8.608×10^{12}
Dielectric Constant			
60 cps	6.904	7.473	7.599
1 kc	6.133	6.721	7.061
10 kc	5.593	6.065	6.083
100 kc	5.078	5.411	5.461
1 mc	4.520	4.774	4.686
Dissipation Factor, %			
60 cps	3.236	7.483	19.727
1 kc	5.968	6.422	7.368
10 kc	7.358	7.800	8.229
100 kc	8.406	8.800	8.999
1 mc	8.549	8.731	8.543
Dielectric Strength, volts/mil	297.1	291.1	296.6
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer)	82	80	80
After 15 Seconds (Type "A_2" Durometer)	79	76	75
Tension (2)			
a. Ultimate Strength, psi	622.1(1)	643.0	657.1
b. Elongation at a. %	(3)	(3)	(3)
c. Yield Strength, psi	606.3	639.8	654.1
d. Youngs Modulus psi	1,389.6	1,564.8	1,600.2
Compression			
a. Yield Strength	–	–	–
b. Youngs Modulus	–	–	–

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

(1) Specimen Number 1 of Control Group never broke. It was stretched 27.5 inches between gage marks (3" gage distance)

(2) Head rate for tension test was 2.0 inches/min.

(3) Specimen elongation was so great that no reliable data was possible - 15" between gage marks (3" gage)

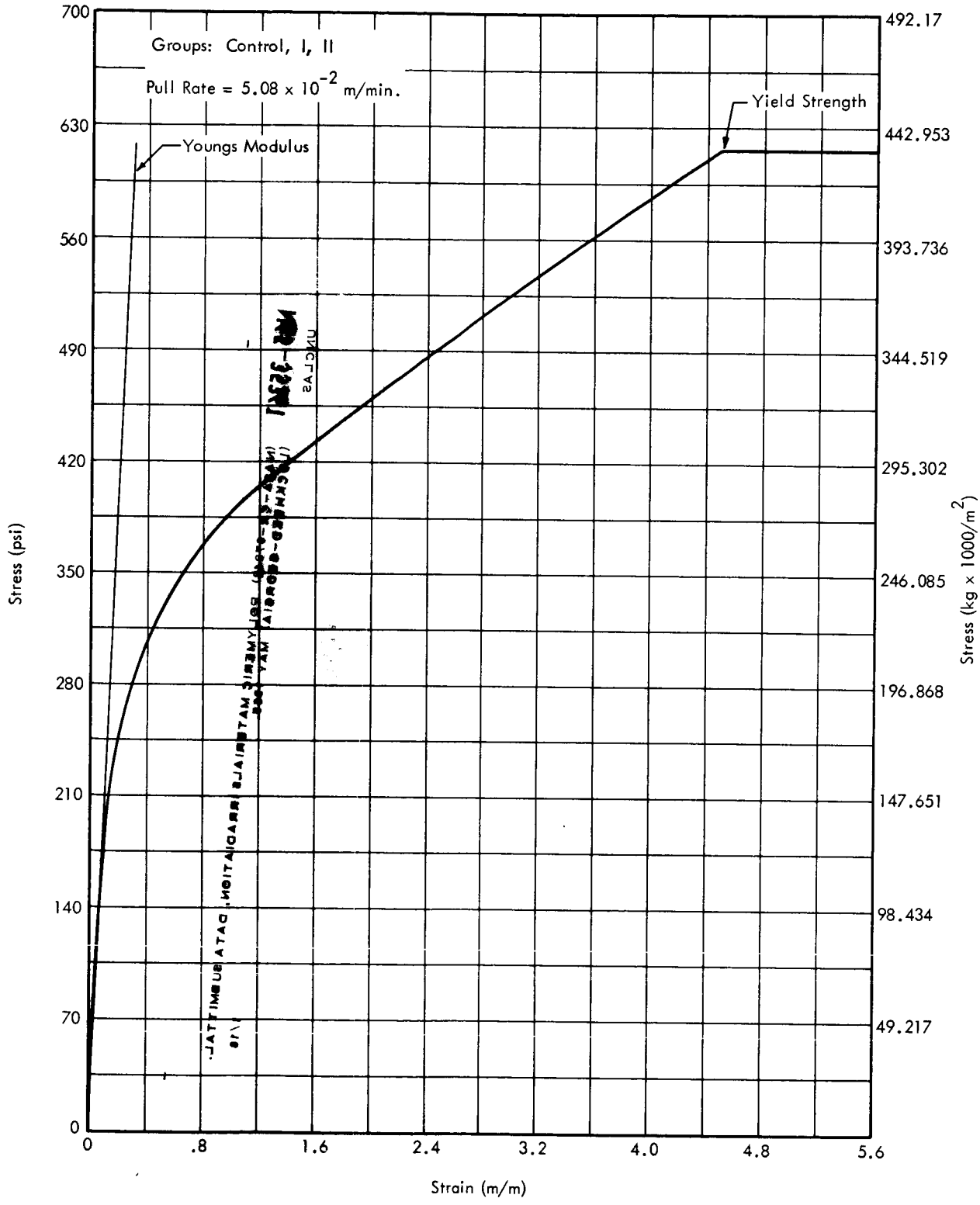

FIGURE 5 TYPICAL TENSION CURVE FOR PR1538

TABLE 3

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: STYCAST 2651

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	$>3.045 \times 10^{14}$	$>96.915 \times 10^{14}$	$>68.797 \times 10^{14}$
Dielectric Constant			
60 cps	5.060	5.142	5.116
1 kc	4.817	4.645	4.693
10 kc	4.677	4.444	4.507
100 kc	4.516	4.326	4.375
1 mc	4.332	4.198	4.228
Dissipation Factor, %			
60 cps	2.488	6.117	5.712
1 kc	2.538	3.731	3.632
10 kc	2.306	2.797	2.738
100 kc	2.557	2.639	2.471
1 mc	2.576	2.365	2.262
Dielectric Strength, volts/mil	359.0	306.0	311.9
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds (Rockwell Hardness)	M98	M93	M95
Tension (1)			
a. Ultimate Strength, psi	8,512	6,584	–
b. Elongation at a. %	9.40	7.50	–
c. Yield Strength, psi	8,512	6,584	–
d. Youngs Modulus, psi	92,697	89,436	–
Compression			
a. Yield Strength, psi	17,846	19,627	19,744
b. Youngs Modulus, psi	767,997	674,712	702,109

*Group I received 5×10^{5} r and 5×10^{11} n/cm^2

**Group II received 5×10^{5} r and 5×10^{14} n/cm^2

(1) Tension curve similar to C1 - 15%, Figure 8

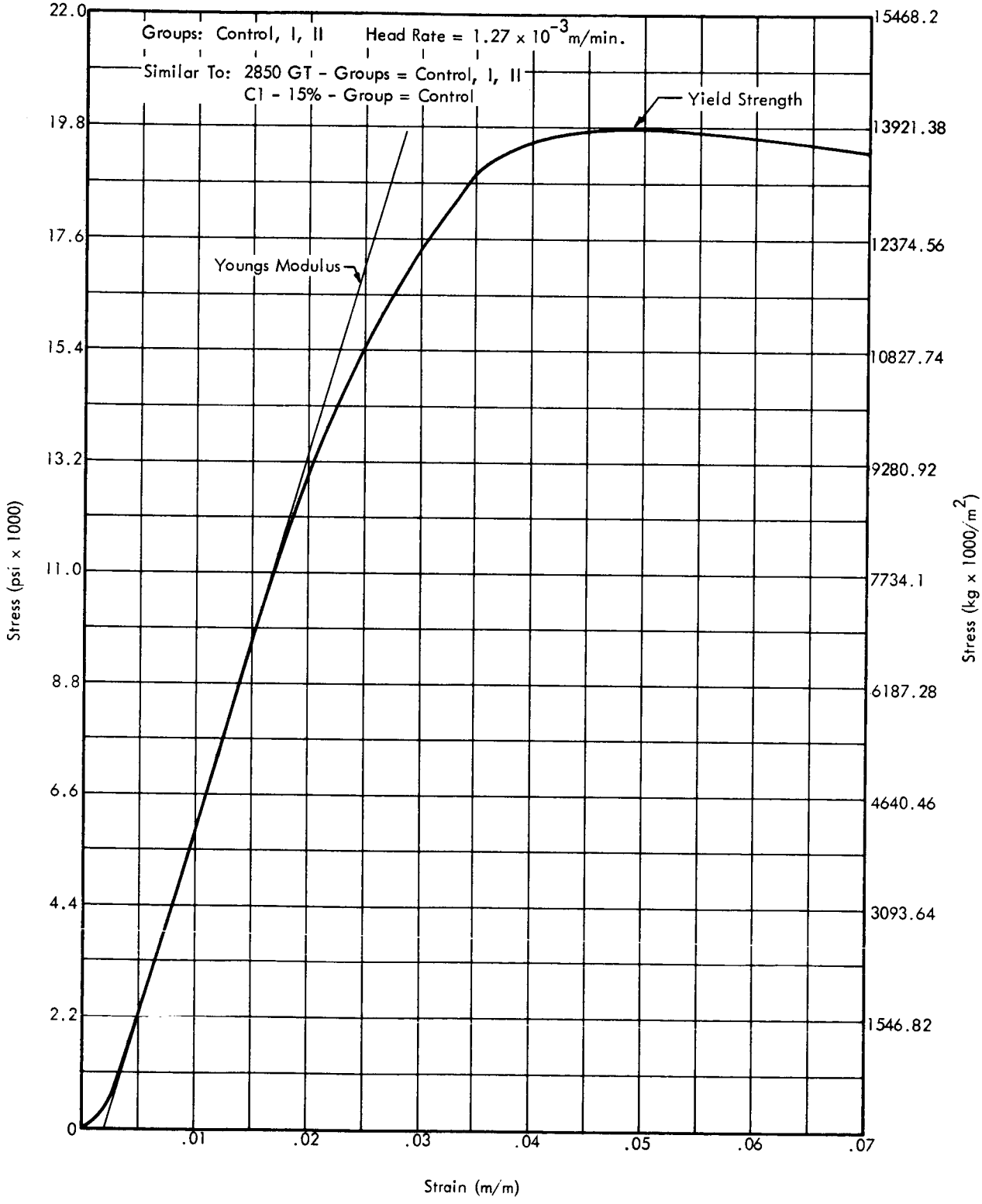

FIGURE 6 TYPICAL COMPRESSION CURVE FOR STYCAST 2651

TABLE 4

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: STYCAST 2850 GT

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	2.917×10^{14}		14.367×10^{14}
Dielectric Constant			
60 cps	5.963		6.246
1 kc	5.968		6.110
10 kc	5.926		6.031
100 kc	5.811		5.991
1 mc	5.690		5.822
Dissipation Factor, %			
60 cps	0.680		0.530
1 kc	0.736		0.892
10 kc	0.939		1.322
100 kc	1.301		1.786
1 mc	1.544		2.000
Dielectric Strength, volts/mil	304.8		286.3
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds (Rockwell Hardness)	M106		M108
Tension (1)			
a. Ultimate Strength, psi	8,474	8,587	7,856
b. Elongation at a. %	8.20	7.716	6.744
c. Yield Strength, psi	8,474	8,587	7,856
d. Youngs Modulus, psi	104,574	113,166	118,755
Compression (2)			
a. Yield Strength, psi	25,021	27,294	26,907
b. Youngs Modulus, psi	1,250,342	1,074,370	1,132,689

*Group I received 5×10^{5} r and 5×10^{11} n/cm^2

**Group II received 5×10^{5} r and 5×10^{14} n/cm^2

(1) Tension curve similar to that of C1 - 15% Figure 8

(2) Compression curve similar to that of 2651 Figure 6

TABLE 5

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: C1 - 15%

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	$> 100.623 \times 10^{14}$	–	2.781×10^{14}
Dielectric Constant			
60 cps	4.796	–	4.391
1 kc	4.498	–	4.398
10 kc	4.433	–	4.277
100 kc	4.181	–	4.020
1 mc	3.863	–	3.532
Dissipation Factor, %			
60 cps	6.506	–	1.865
1 kc	3.406	–	2.676
10 kc	3.573	–	2.943
100 kc	4.526	–	3.696
1 mc	5.261	–	4.764
Dielectric Strength, volts/mil	326.0	–	317.1
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds (Rockwell Hardness)	M54	–	M68
Tension			(1 Specimen)
a. Ultimate Strength, psi	8,825	–	5,413
b. Elongation at a. %	20.356	–	10.467
c. Yield Strength, psi	8,825	–	5,413
d. Secant Modulus, psi	56,133	–	52,455
Compression			
a. Yield Strength, psi	11,293	–	–
b. Youngs Modulus, psi	304,914	–	–

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

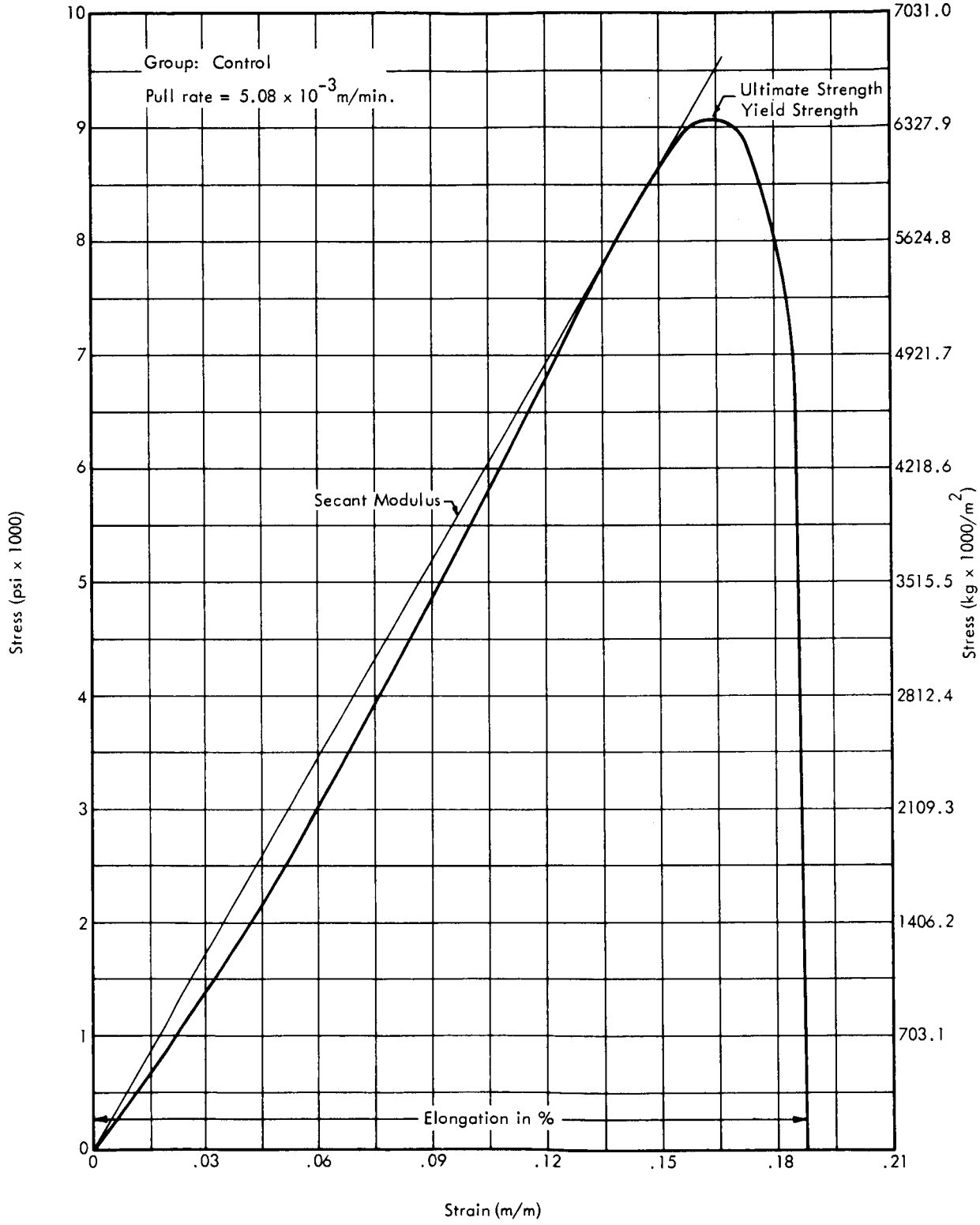

FIGURE 7 TYPICAL TENSION CURVE FOR C1 -15%

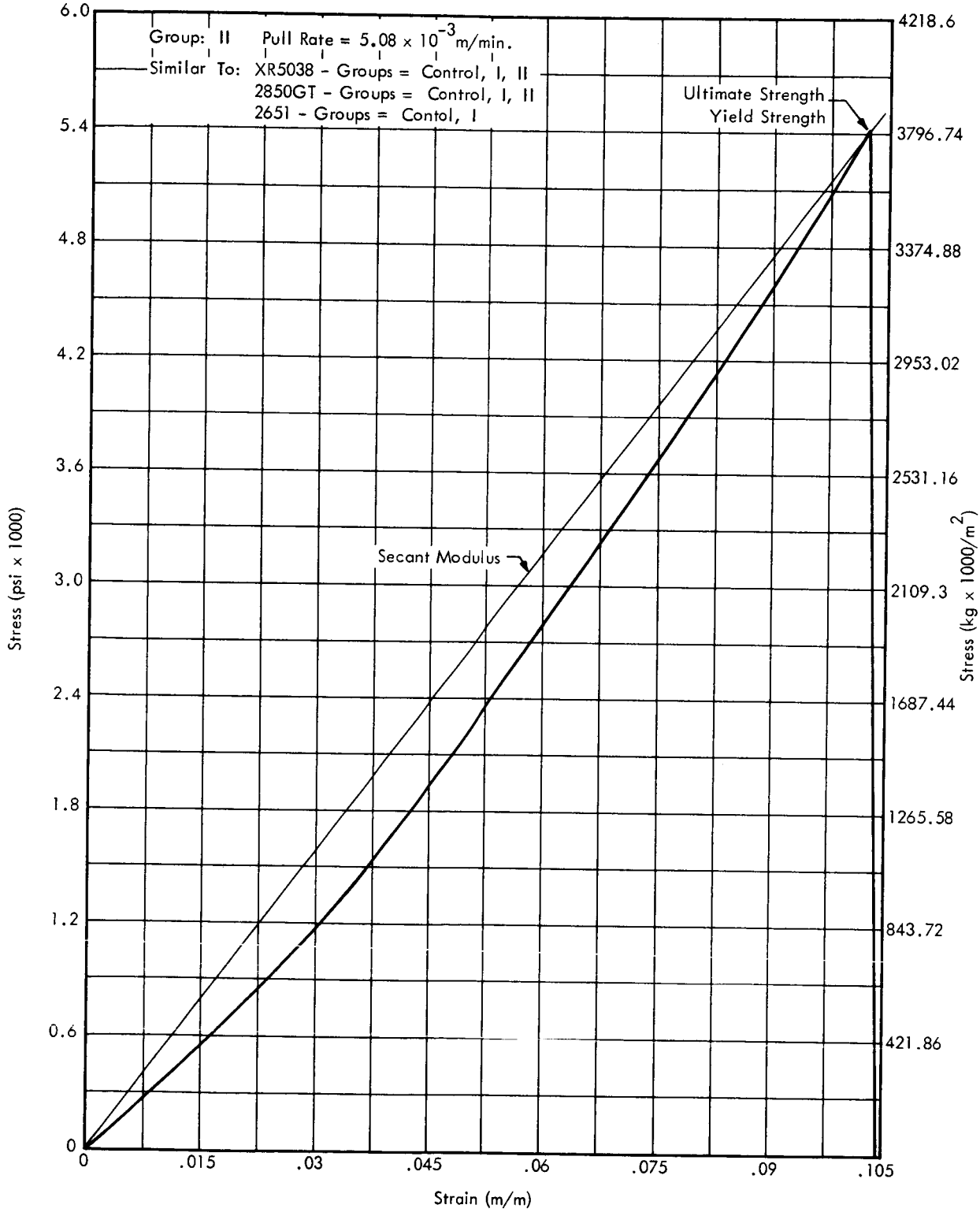

FIGURE 8 TYPICAL TENSION CURVE FOR C1 - 15%

TABLE 6

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: C1 - 75%

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	7.605×10^{10}	268.543×10^{10}	15.651×10^{10}
Dielectric Constant			
60 cps	20.347	15.682	13.706
1 kc	8.579	9.545	10.351
10 kc	7.281	7.330	7.910
100 kc	6.363	6.160	7.152
1 mc	5.428	5.287	5.568
Dissipation Factor, %			
60 cps	113.436	108.121	97.043
1 kc	25.367	33.451	39.834
10 kc	13.570	15.456	17.203
100 kc	10.255	10.295	10.163
1 mc	11.773	11.532	11.798
Dielectric Strength, volts/mil	139.8	121.8	125.4
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer	55	49	56
After 15 Seconds (Type "A_2" Durometer	51	43	49
Tension (1)			
a. Ultimate Strength, psi	181.58	230.763	266.214
b. Elongation at a. %	122.833	132.0	118.0
c. Yield Strength, psi	181.58	230.763	266.214
d. Youngs Modulus, psi	155.622	176.07	229.644
Compression			
a. Yield Strength, psi	16,880	914.1	916.9
b. Secant Modulus, psi	See Typical Curve	1,870	2,097

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

(1) Tension curve similar to Polyoloein, Figure 14

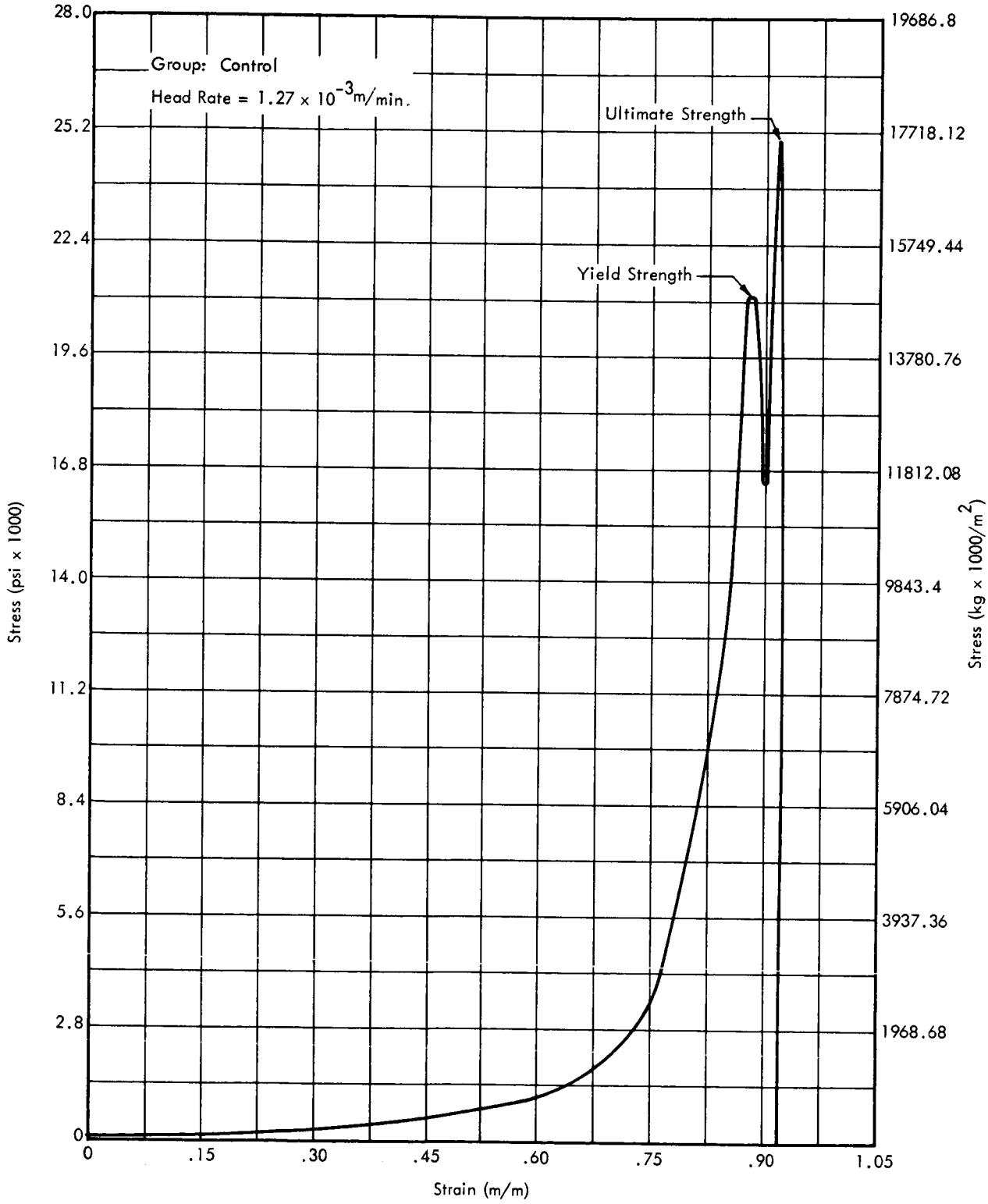

FIGURE 9 TYPICAL COMPRESSION CURVE FOR C1 - 75%

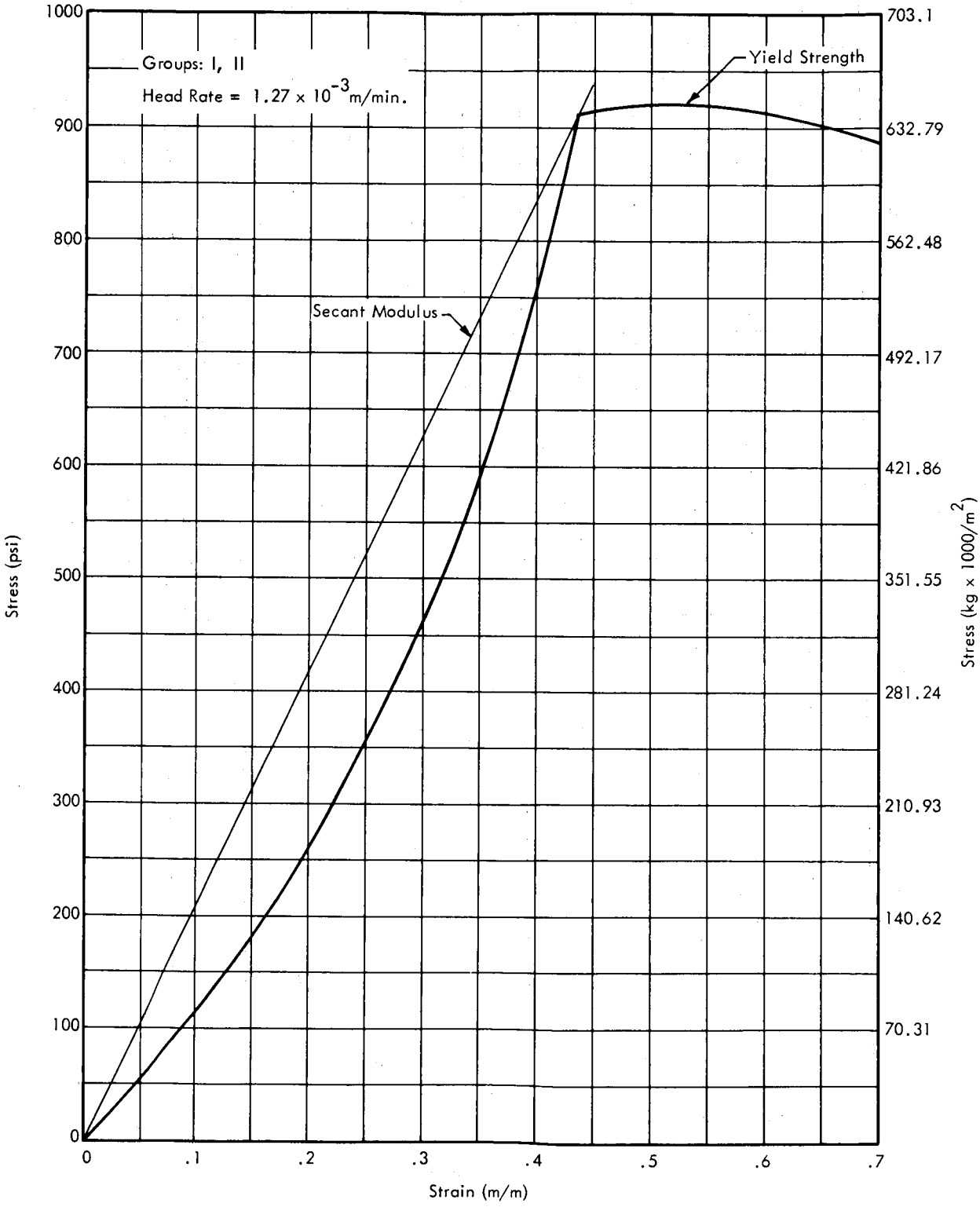

FIGURE 10 TYPICAL COMPRESSION CURVE FOR C1 - 75%

TABLE 7

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: EC 1663

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	$>15.132 \times 10^{15}$	$>75.710 \times 10^{14}$	$>38.900 \times 10^{14}$
Dielectric Constant			
60 cps	(1) 4.161	4.364	4.367
1 kc	(1) 4.060	4.179	4.195
10 kc	(1) 4.006	4.068	4.059
100 kc	(1) 3.979	4.021	4.062
1 mc	(1) 3.982	3.981	3.999
Dissipation Factor, %			
60 cps	(1) 0.735	2.810	3.044
1 kc	(1) 1.102	2.175	2.242
10 kc	(1) 0.674	1.506	1.492
100 kc	(1) 0.403	0.816	0.777
1 mc	(1) 0.286	0.379	0.350
Dielectric Strength, volts/mil	325.7	330.2	350.2
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer)	46	52	55
After 15 Seconds (Type "A_2" Durometer)	46	51	53
Tension			
a. Ultimate Strength, psi			
b. Elongation at a. %			
c. Yield Strength, psi			
d. Youngs Modulus, psi			
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5r and 5×10^{11} n/cm^2

**Group II received 5×10^5r and 5×10^{14} n/cm^2

(1) 1.5" Diameter Specimen

TABLE 8

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: G10 FIBERGLASS

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil	(1)	(1)	(1)
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		45,735	46,951
b. Elongation at a. %		6.279	6.286
c. Yield Strength, psi		45,735	46,951
d. Youngs Modulus, psi		742,932	764,295
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2 - Specimens of this group became brown during irradiation.

(1) No Breakdown: Current traveled around the edge of the specimen surface.

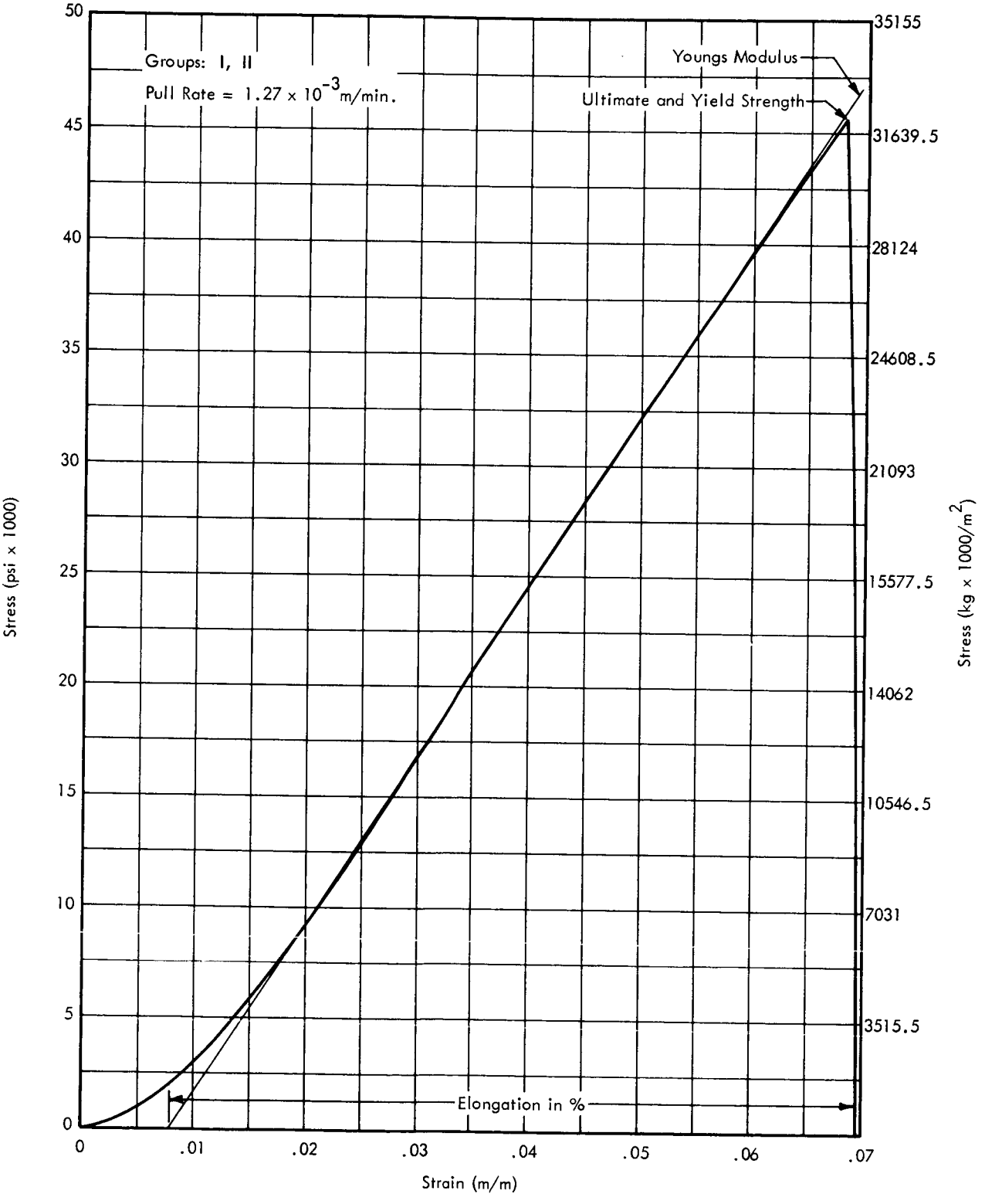

FIGURE 11 TYPICAL TENSION CURVE FOR G-10 FIBERGLASS

TABLE 9

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: LTV182

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	$> 14.800 \times 10^{15}$	4.173×10^{14}	$> 20.523 \times 10^{15}$
Dielectric Constant			
60 cps	(1) 2.751	2.864	2.839
1 kc	(1) 2.829	2.849	2.850
10 kc	(1) 2.827	2.868	2.868
100 kc	(1) 2.823	2.846	2.851
1 mc	(1) 2.811	2.850	2.855
Dissipation Factor, %			
60 cps	(1) 1.018	1.067	0.680
1 kc	(1) 0.076	0.078	0.093
10 kc	(1) 0.106	0.094	0.112
100 kc	(1) 0.128	0.251	0.136
1 mc	(1) 0.144	0.125	0.128
Dielectric Strength, volts/mil	358.3	> 404.0	366.2
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer)	44	46	48
After 15 Seconds (Type "A_2" Durometer)	44	46	48
Tension			
a. Ultimate Strength, psi			
b. Elongation at a. %			
c. Yield Strengtn, psi			
d. Youngs Modulus, psi			
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

(1) 1.5" Diameter Specimen

TABLE 10

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: LTV602

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	–	$>14.760 \times 10^{15}$	$>10.042 \times 10^{15}$
Dielectric Constant			
60 cps	–	13.086	2.781
1 kc	–	2.818	2.787
10 kc	–	2.818	2.804
100 kc	–	2.773	2.837
1 mc	–	2.756	2.804
Dissipation Factor, %			
60 cps	–	0.236	0.649
1 kc	–	0.099	0.120
10 kc	–	0.140	0.144
100 kc	–	0.141	0.152
1 mc	–	0.453	0.280
Dielectric Strength, volts/mil	–	345.0	346.6
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer)		25	25
After 15 Seconds(Type "A_2" Durometer)		11	24
Tension			
a. Ultimate Strength, psi	(1)	(1)	(1)
b. Elongation at a. %	(1)	(1)	(1)
c. Yield Strength, psi	(1)	(1)	(1)
d. Youngs Modulus, psi	(1)	(1)	(1)
Compression			
a. Yield Strength, psi	(2)	(2)	(2)
b. Youngs Modulus, psi	(2)	(2)	(2)

*Group I received 5×10^5r and 5×10^{11} n/cm^2

**Group II received 5×10^5r and 5×10^{14} n/cm^2

(1) No data: Specimen would not hold in fixture.

(2) No data: Specimen would fold in fixture.

TABLE 11

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: 3M PVC

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil		917.2	1125.4
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension (1)			
a. Ultimate Strength, psi		3,550	3,491
b. Elongation at a. %		276.25	277.0
c. Yield Strength, psi		3,550	3,491
d. Youngs Modulus, psi		1,285.244	1,277.228
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5r and 5×10^{11} n/cm^2

**Group II received 5×10^5r and 5×10^{14} n/cm^2

(1) Tension curve similar to Polyoloein, Figure 14

TABLE 12

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: MYLAR FILM

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil			
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		17,259	17,710
b. Elongation at a. %		43.642	50.119
c. Yield Strength, psi		13,494	13,399
d. Youngs Modulus , psi		462,273	463,134
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

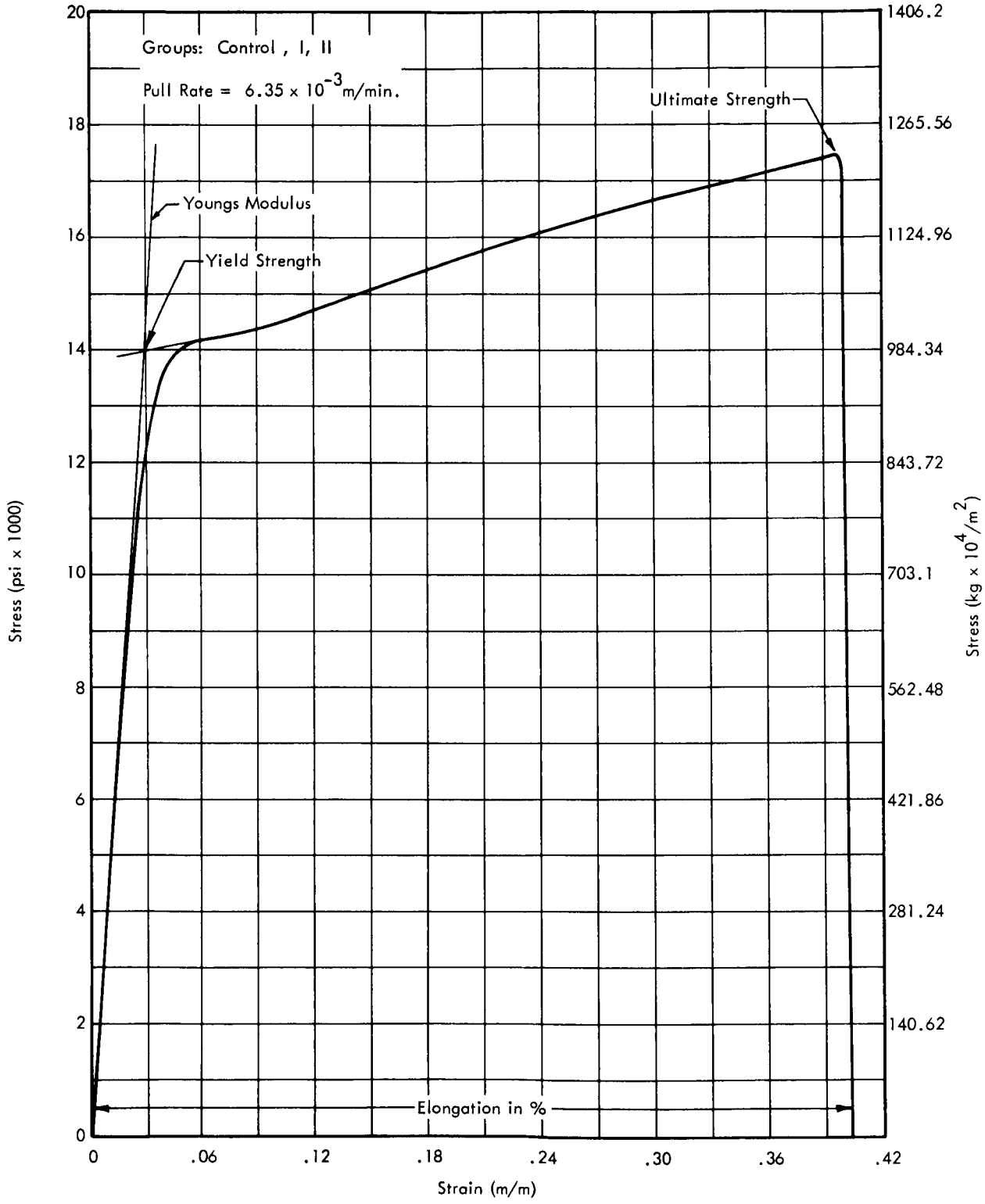

FIGURE 12 TYPICAL TENSION CURVE FOR MYLAR FILM

TABLE 13

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: P. O. RAYCLAD

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil			
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		2,270	2,494
b. Elongation at a. %		341.5	374.334
c. Yield Strength, psi		2,099	2,143
d. Youngs Modulus, psi		47,682	49,876
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

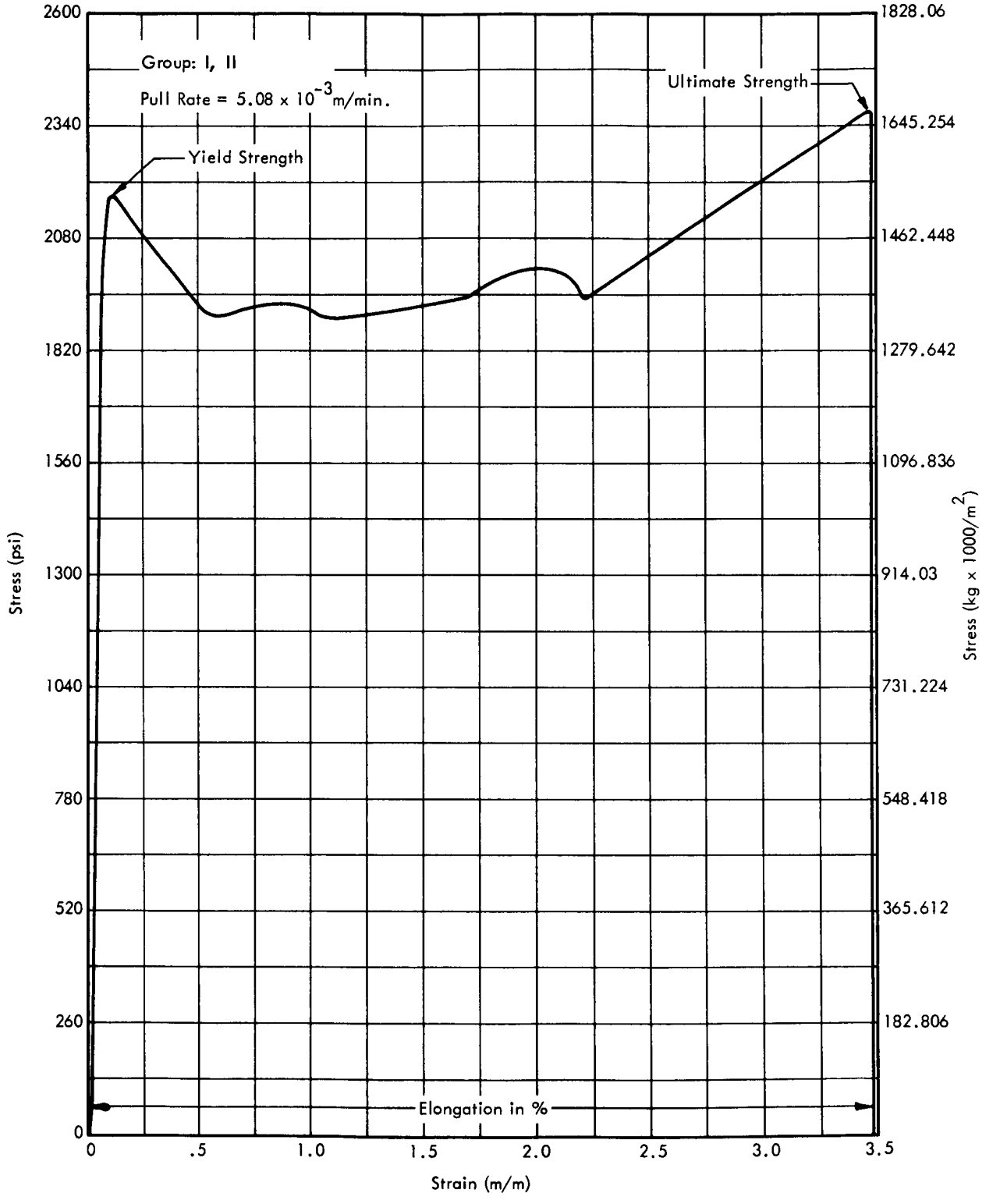

FIGURE 13 TYPICAL TENSION CURVE FOR P. O. RAYCLAD SLEEVING

TABLE 14

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: POLYOLOEIN

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil			
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		3,419	3,306
b. Elongation at a. %		289.733	278.677
c. Yield Strength, psi		3,419	3,306
d. Secant Modulus, psi		1,172.7	1,187.55
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

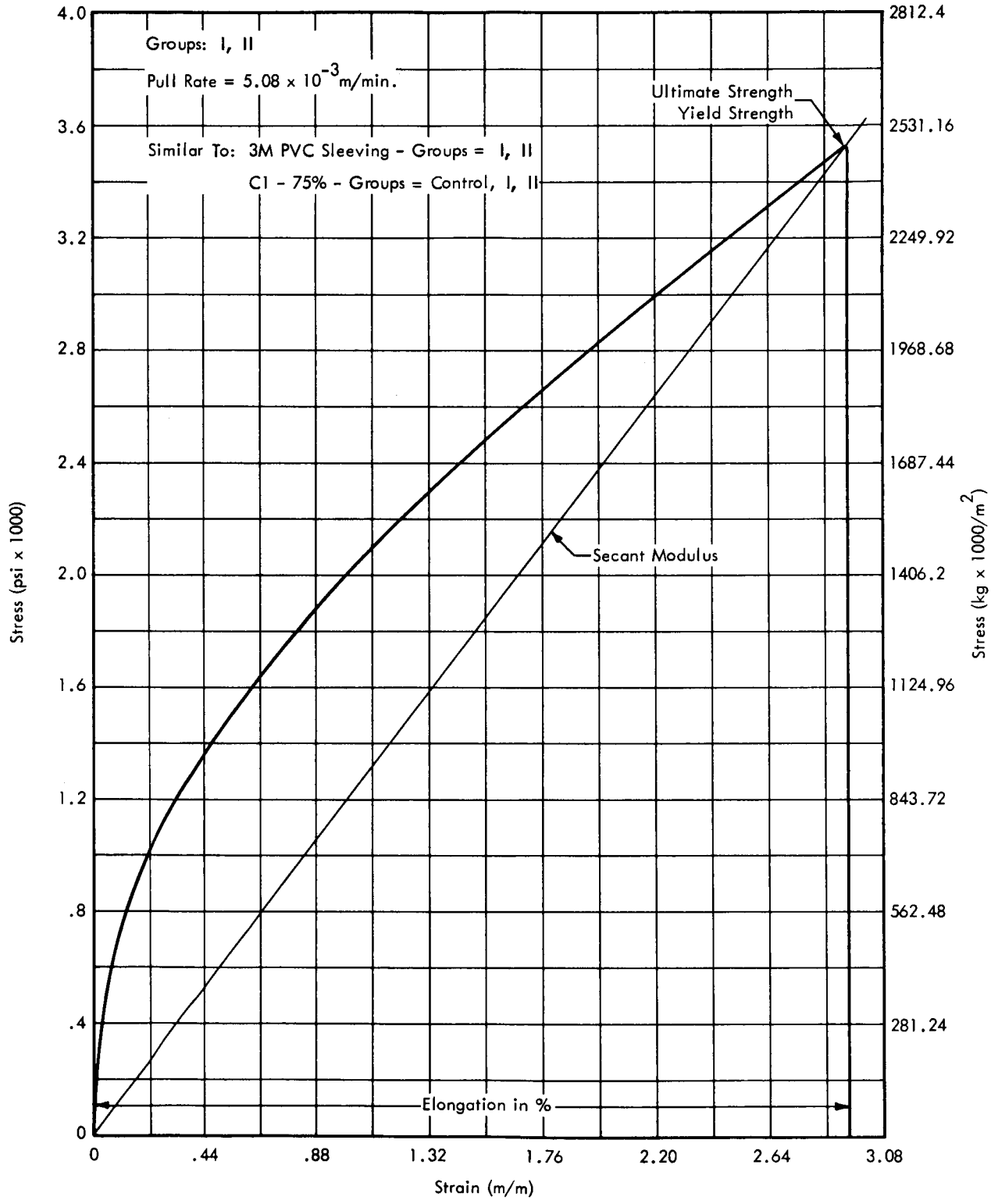

FIGURE 14 TYPICAL TENSION CURVE FOR POLYOLOEIN

TABLE 15

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: RTV 11

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	106.896×10^{12}	80.430×10^{12}	89.780×10^{12}
Dielectric Constant			
60 cps	(1) 3.502	3.568	3.573
1 kc	(1) 3.393	3.463	3.469
10 kc	(1) 3.364	3.364	3.416
100 kc	(1) 3.351	3.391	3.395
1 mc	(1) 3.320	3.364	3.370
Dissipation Factor, %			
60 cps	(1) 1.355	3.536	2.724
1 kc	(1) 0.808	1.223	1.031
10 kc	(1) 0.608	0.817	0.824
100 kc	(1) 0.677	0.694	0.606
1 mc	(1) 0.568	0.494	0.506
Dielectric Strength, volts/mil	363.5	365.7	> 386.6
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer)	48	45	47
After 15 Seconds (Type "A_2" Durometer)	47	45	46
Tension			
a. Ultimate Strength, psi	(2)	(2)	(2)
b. Elongation at a. %	(2)	(2)	(2)
c. Yield Strength, psi	(2)	(2)	(2)
d. Youngs Modulus, psi	(2)	(2)	(2)
Compression			
a. Yield Strength, psi	(3)	(3)	(3)
b. Youngs Modulus, psi	(3)	(3)	(3)

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

(1) 1.5" Diameter Specimen

(2) No data: Could not hold specimens in fixture.

(3) No data: Specimens folded in fixture.

TABLE 16

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: RTV 501

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	27.514×10^{13}	$> 60.958 \times 10^{14}$	17.038×10^{13}
Dielectric Constant			
60 cps	(1) 2.911	3.035	3.024
1 kc	(1) 3.109	2.958	2.995
10 kc	(1) 2.922	2.924	2.953
100 kc	(1) 2.896	2.800	2.948
1 mc	(1) 2.914	2.897	2.943
Dissipation Factor, %			
60 cps	(1) 1.501	1.411	0.808
1 kc	(1) 0.945	1.091	1.135
10 kc	(1) 0.726	0.668	0.682
100 kc	(1) 0.568	0.490	0.413
1 mc	(1) 0.676	0.157	0.189
Dielectric Strength, volts/mil	389.3	366.3	347.6
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact (Type "A_2" Durometer)	44	44	47
After 15 Seconds(Type "A_2" Durometer)	43	43	46
Tension			
a. Ultimate Strength, psi	(2)	(2)	(2)
b. Elongation at a. %	(2)	(2)	(2)
c. Yield Strength, psi	(2)	(2)	(2)
d. Youngs Modulus, psi	(2)	(2)	(2)
Compression			
a. Yield Strength,psi	(3)	(3)	(3)
b. Youngs Modulus, psi	(3)	(3)	(3)

*Group I received 5×10^5r and 5×10^{11} n/cm^2

**Group II received 5×10^5r and 5×10^{14} n/cm^2

(1) 1.5" Diameter Specimen

(2) No data: Specimen would not hold in fixture.

(3) No data: Specimen folded in fixture.

TABLE 17

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: SILICONE RUBBER SLEEVING

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil		780.9	744.3
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		917.7	1,275.2
b. Elongation at a. %		435.1	413.7
c. Yield Strength, psi		917.7	1,275.2
d. Youngs Modulus, psi		182.204	271.808
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

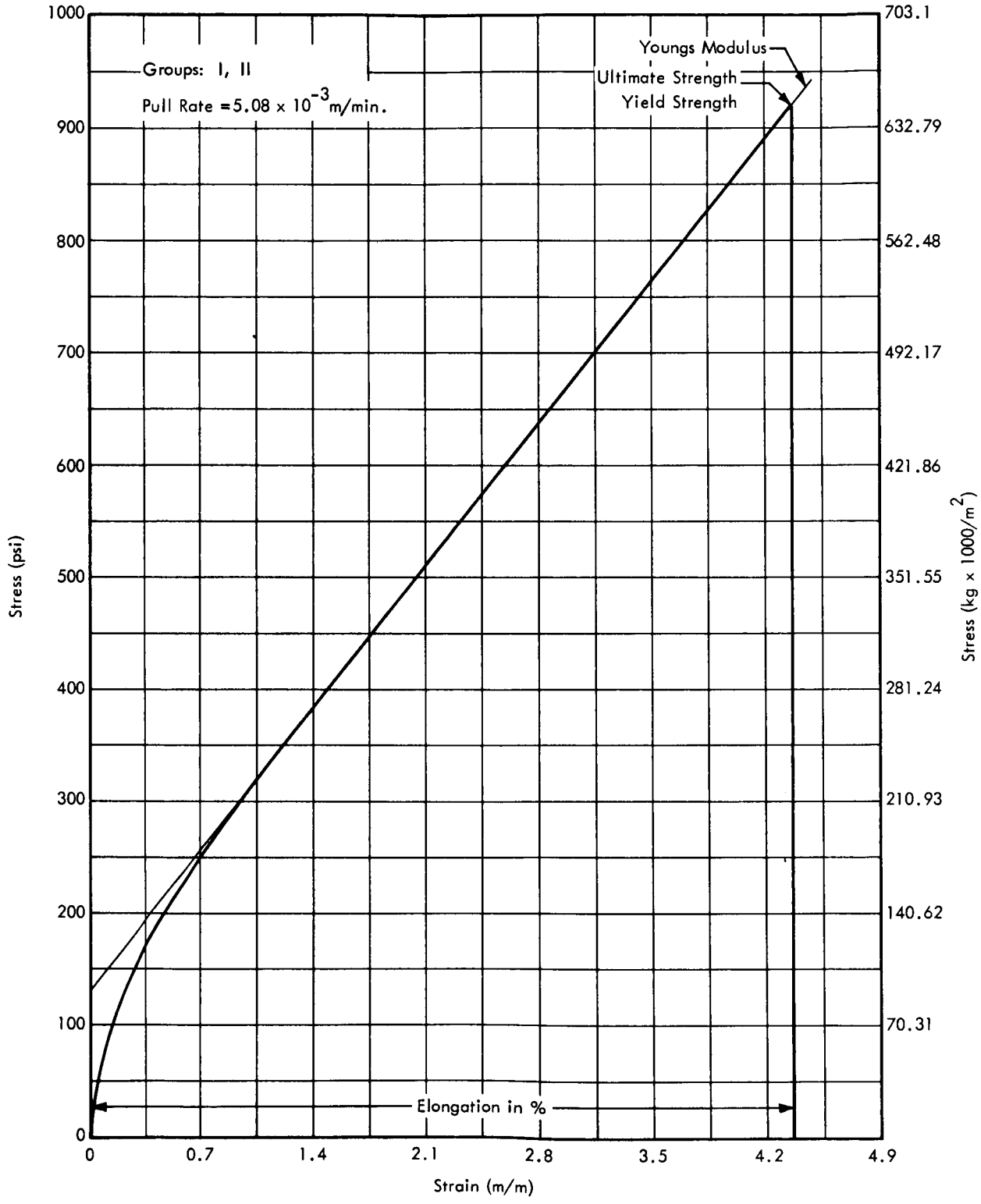

FIGURE 15 TYPICAL TENSION CURVE FOR SILICONE RUBBER

TABLE 18

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: TFE RAYCLAD

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil			
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		3,223	2,641
b. Elongation at a. %		357.556	285.333
c. Yield Strength, psi		1,623	1,797
d. Youngs Modulus, psi		52,838	61,742
Compression			
a. Yield Strength, psi			
b. Youngs Modulus, psi			

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

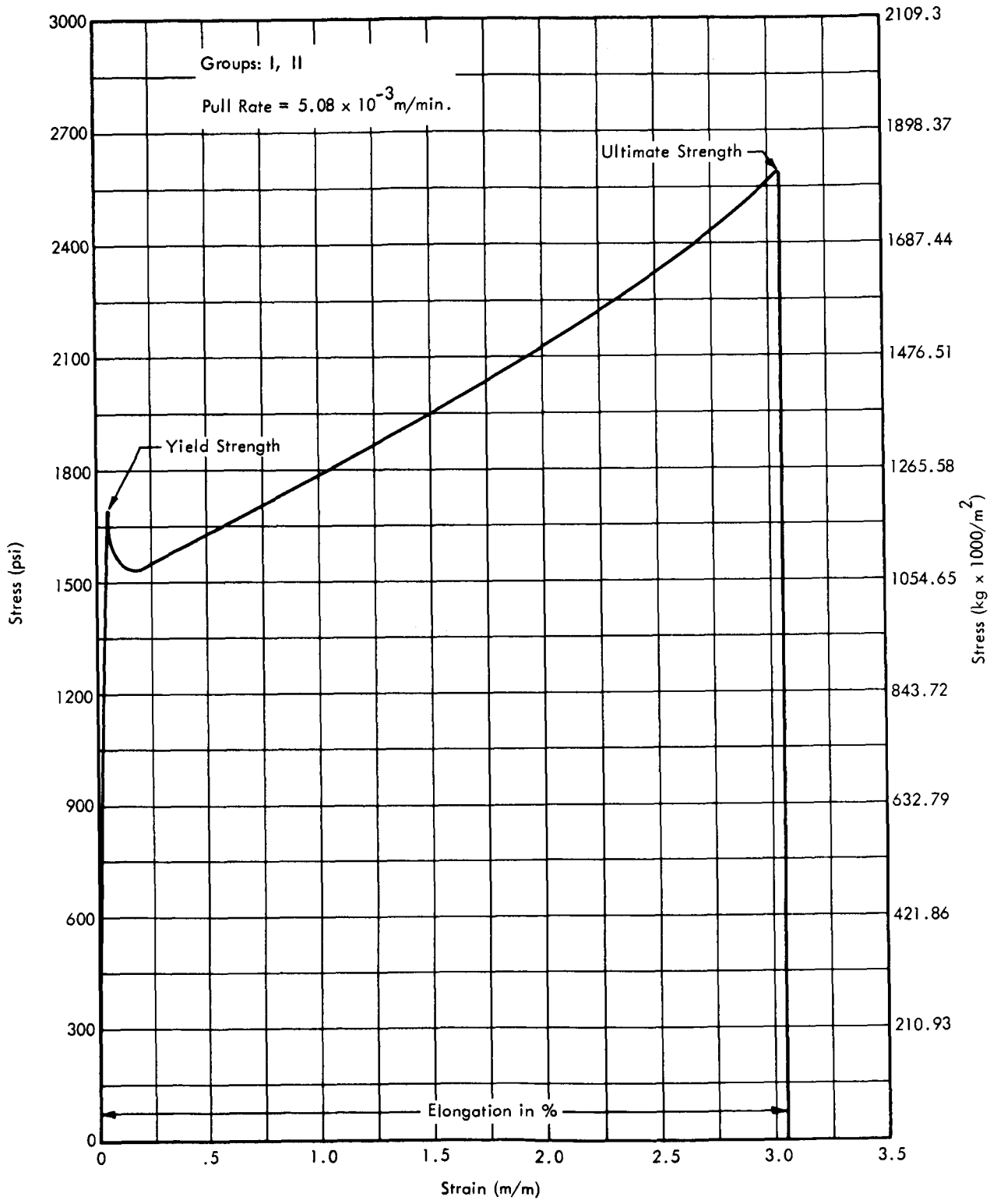

FIGURE 16 TYPICAL TENSION CURVE FOR TFE RAYCLAD SLEEVING

TABLE 19

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: TEFLON

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm			
Dielectric Constant			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dissipation Factor, %			
60 cps			
1 kc			
10 kc			
100 kc			
1 mc			
Dielectric Strength, volts/mil			
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds			
Tension			
a. Ultimate Strength, psi		1,653	1,527
b. Elongation at a. %		165.222	70.150
c. Yield Strength, psi		1,459	1,465
d. Youngs Modulus, psi		102,780	106,953
Compression			
a. Yield Strength, psi	20,825	886.9	887.5
b. Youngs Modulus, psi	See Typical Curve	43,986	49,077

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

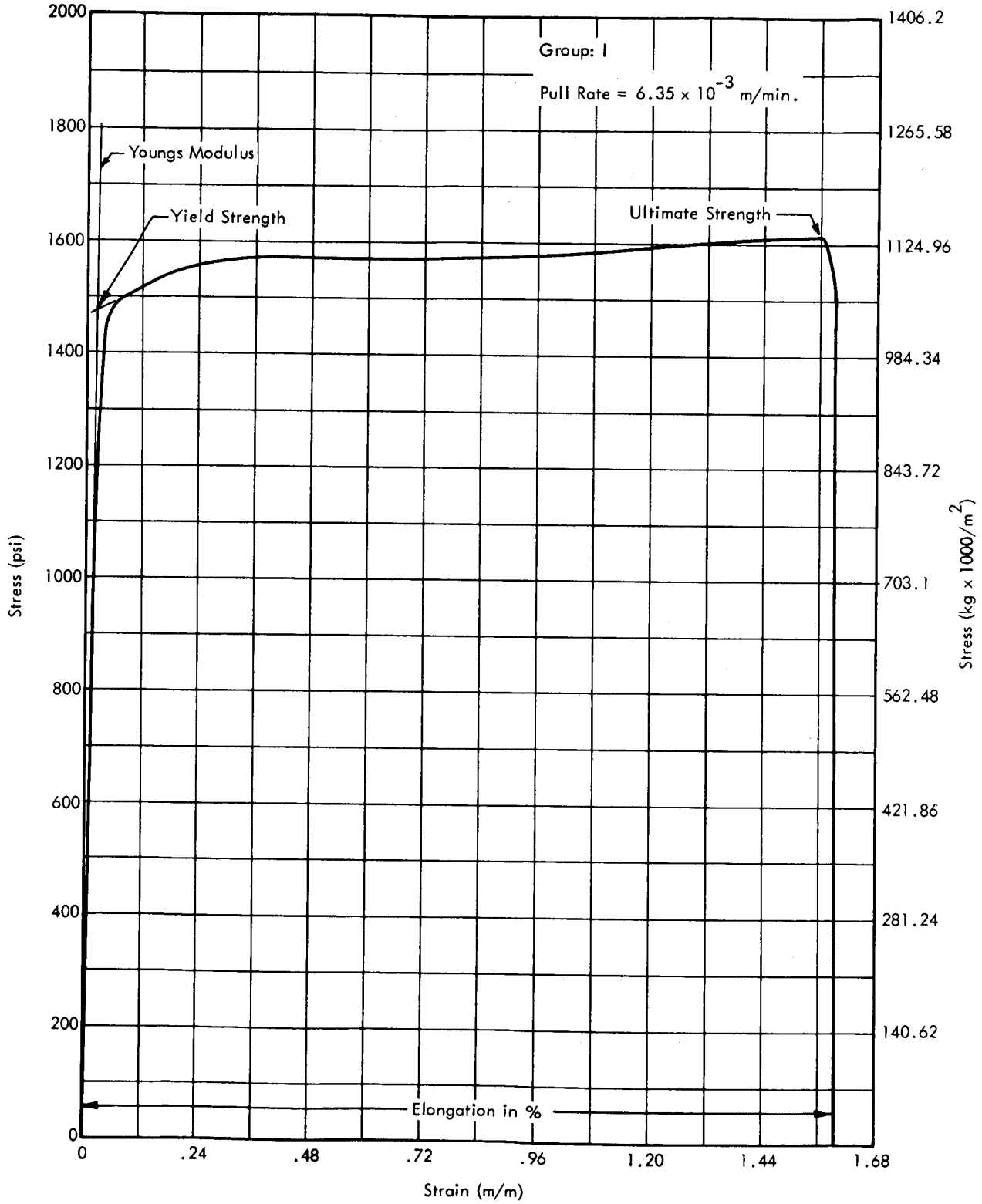

FIGURE 17 TYPICAL TENSION CURVE FOR TEFLON

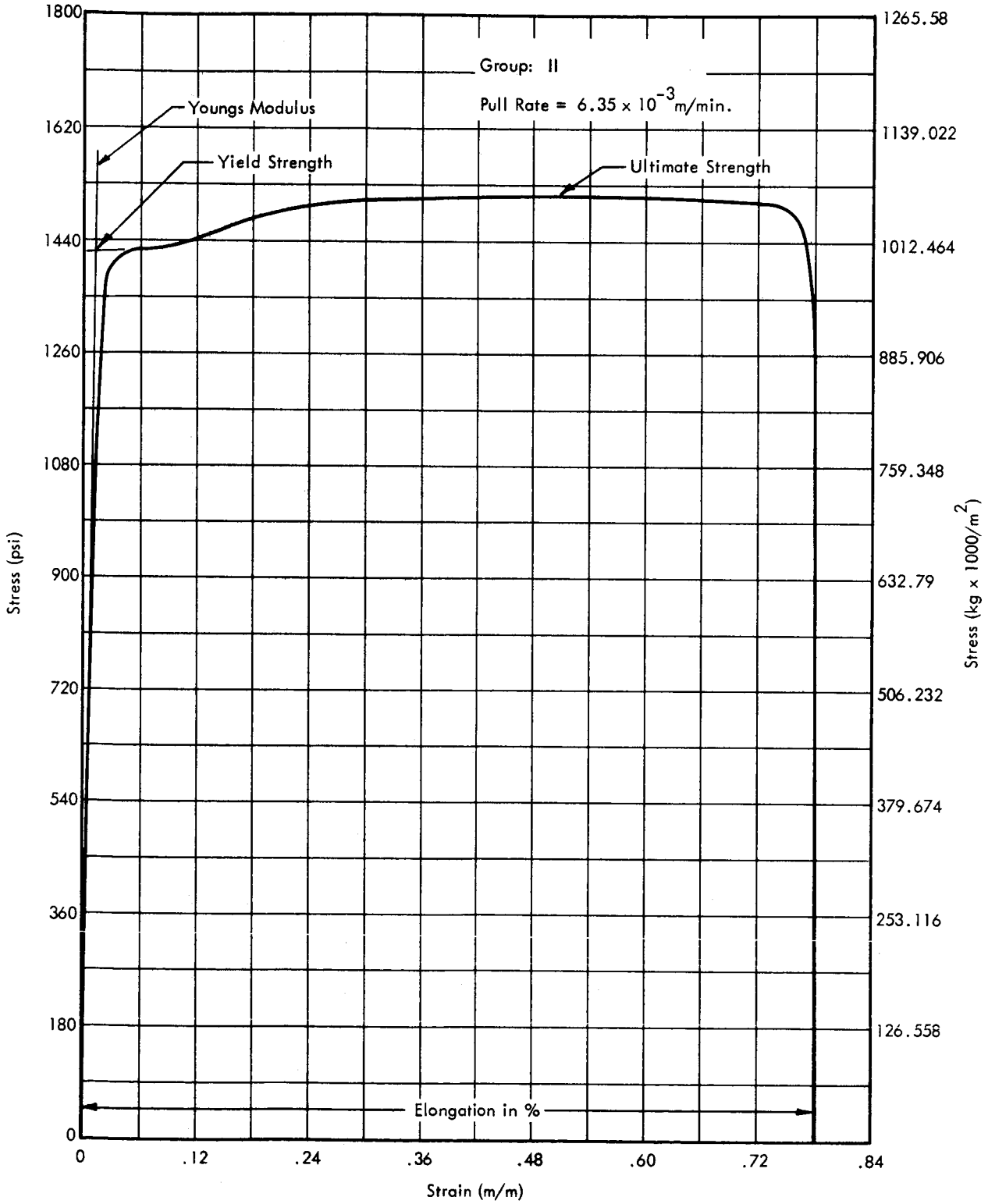

FIGURE 18 TYPICAL TENSION CURVE FOR TEFLON

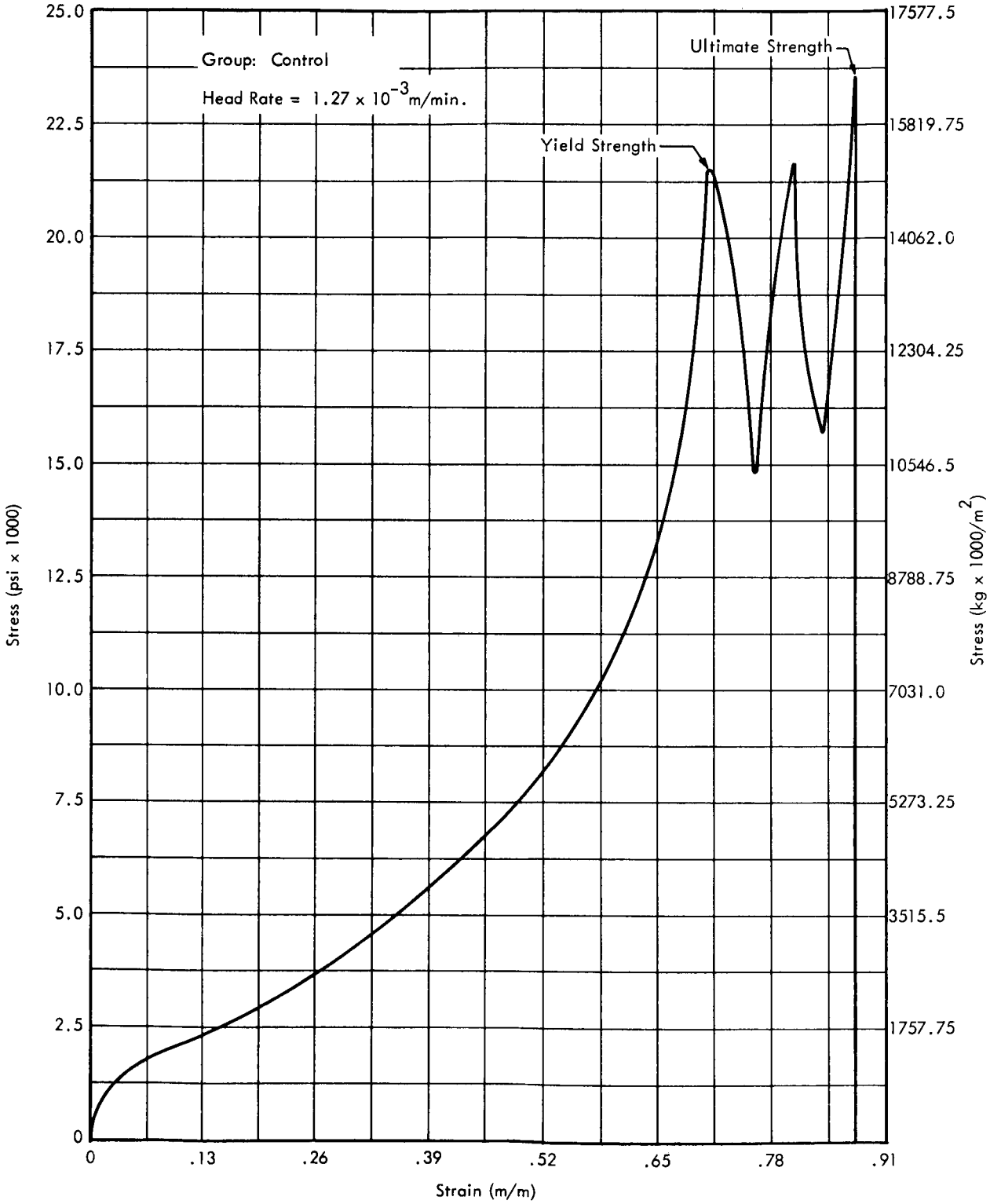

FIGURE 19 TYPICAL COMPRESSION CURVE FOR TEFLON

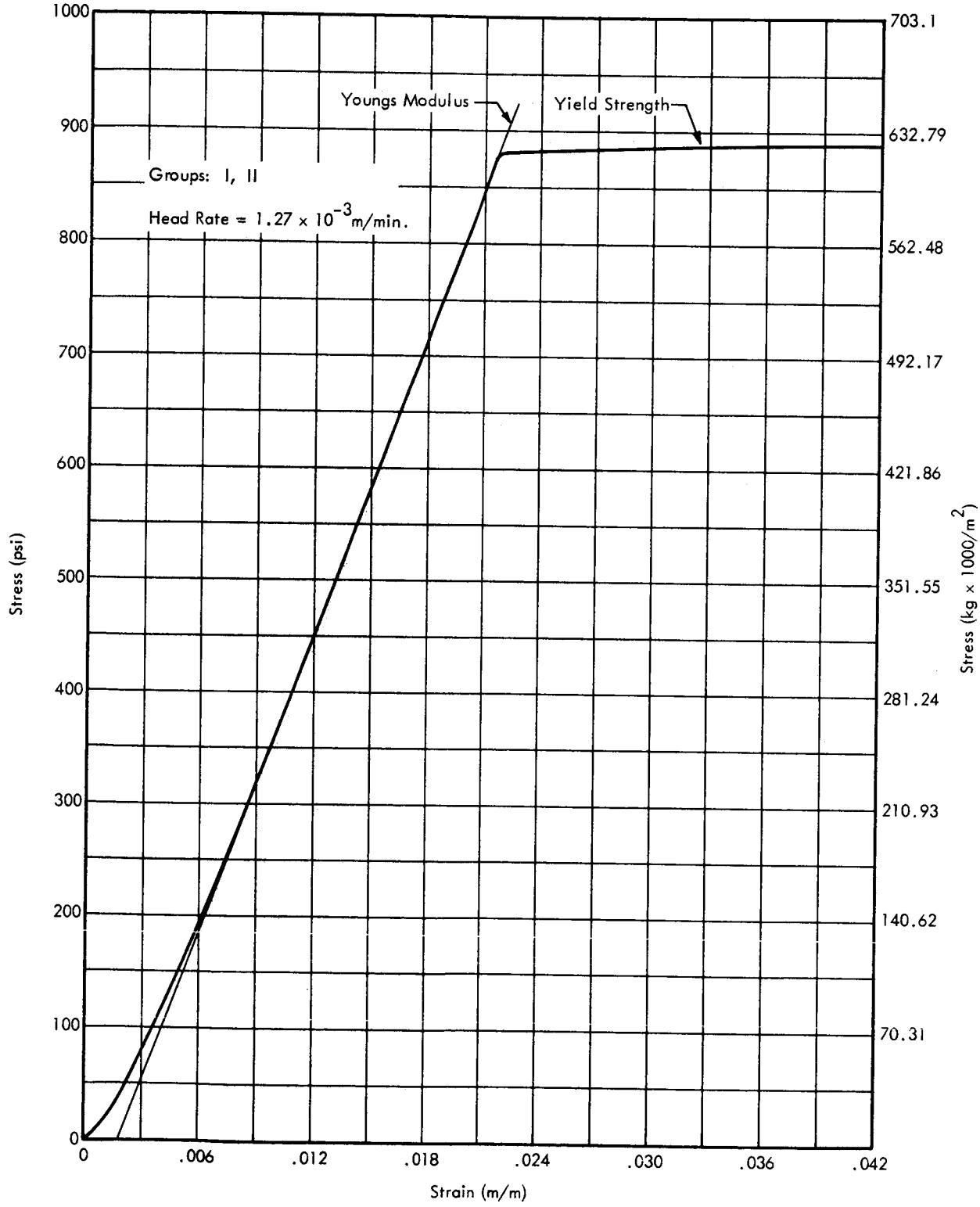

FIGURE 20 TYPICAL COMPRESSION CURVE FOR TEFLON

TABLE 20

ELECTRICAL AND PHYSICAL CHARACTERISTICS OF

MATERIAL: XR5038

PARAMETER	CONTROL	GROUP I*	GROUP II**
ELECTRICAL CHARACTERISTICS			
Resistivity, ohm-cm	3.037×10^{14}	11.972×10^{14}	7.788×10^{14}
Dielectric Constant			
60 cps	4.311	4.518	4.549
1 kc	4.075	4.171	4.204
10 kc	3.923	3.875	3.978
100 kc	3.774	3.829	3.851
1 mc	3.656	3.670	3.675
Dissipation Factor, %			
60 cps	3.428	5.213	5.585
1 kc	2.947	3.766	3.896
10 kc	2.642	3.100	3.383
100 kc	2.409	3.046	3.073
1 mc	1.978	2.533	2.440
Dielectric Strength, volts/mil	315.8	347.8	342.1
PHYSICAL CHARACTERISTICS			
Hardness			
At Contact			
After 15 Seconds (Rockwell Hardness)	M95	M89	M82
Tension (1)			
a. Ultimate Strength, psi	4,456	4,400	5,149
b. Elongation at a. %	8.65	8.384	9.192
c. Yield Strength, psi	4,456	4,400	5,149
d. Secant Modulus, psi	52,191	52,140	56,988
Compression			
a. Yield Strength,psi	10,763	13,928	14,105
b. Youngs Modulus,psi	347,900	460,900	469,036

*Group I received 5×10^5 r and 5×10^{11} n/cm^2

**Group II received 5×10^5 r and 5×10^{14} n/cm^2

(1) Tension curve similar to C1 - 15%; Figure 8

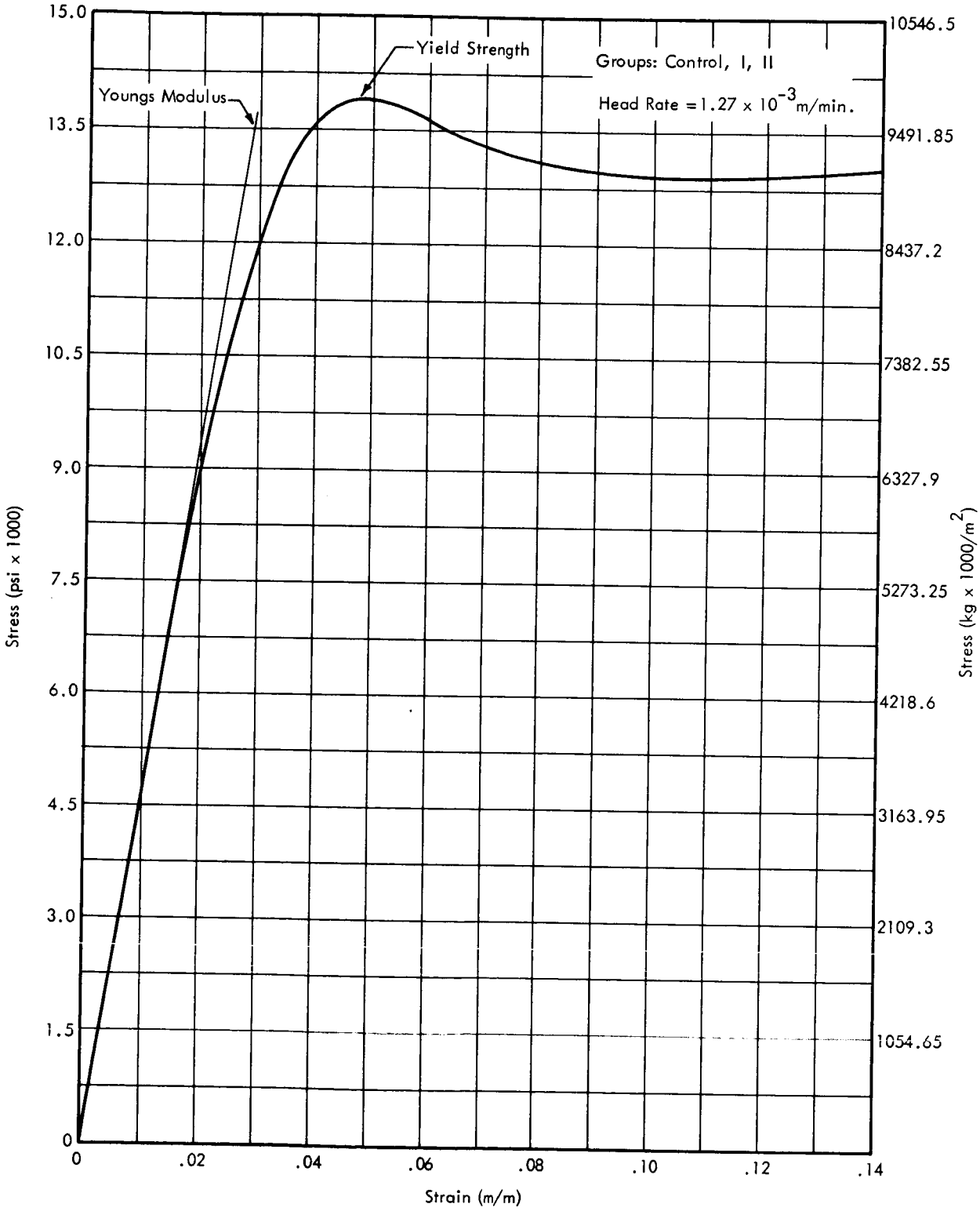

FIGURE 21 TYPICAL COMPRESSION CURVE FOR XR 5038